VEHICLE CONTROL UNIT(VCU)

**Example.**

"Analysis of an AUTOSAR-Oriented and CAN-Integrated Vehicle Control Unit and Architecture for a 2-Wheeler Electric Vehicle"

Report submitted to GITAM (Deemed to be University) as a partial fulfillment of the requirements for the award of the Degree of Bachelor of Technology in (write your respective branch)



DEPARTMENT OF ELECTRICAL, ELECTRONICS AND COMMUNICATION ENGINEERING

GITAM SCHOOL OF TECHNOLOGY

GITAM (DEEMED TO BE UNIVERSITY)

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**DECLARATION**

I/We declare that the project work contained in this report is original and it has been done by me under the guidance of my project guide.

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**CERTIFICATE**

This is to certify that (BHARATH J, MANOHAR R, CHANDU C) bearing (Regd. No.: BU22EECE0100479, BU22EECE0100302, BU22EECE0100480) has satisfactorily completed Mini Project Entitled in partial fulfillment of the requirements as prescribed by University for VIIth semester, Bachelor of Technology in “Electrical, Electronics and Communication Engineering” and submitted this report during the academic year 2025-2026.

[Signature of the Guide] [Signature of HOD]

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**Chapter 1: Introduction**

* 1. Overview of the problem statement

The core problem addressed by this project is the lack of a standardized, robust, and cost-effective **Vehicle Control Unit (VCU) architecture** for two-wheeler Electric Vehicles (EVs). The project seeks to solve this by creating a VCU design that adheres to the **AUTOSAR standards** to ensure modularity, reusability, and software portability. A major challenge is establishing **dependable communication** among critical EV subsystems—the BMS, Motor Controller, and User Interface—which is resolved through the implementation of the **CAN protocol**. Ultimately, the VCU must be designed to be strong, economical, easy to service , and scalable for future features , all while efficiently managing resources under the tighter space and cost constraints inherent to two-wheeler platforms.

* 1. Objectives and goals

**Primary Objective:** To create a standardized **Vehicle Control Unit (VCU) design architecture** corresponding to **AUTOSAR standards** for two-wheeler electric vehicles.

**Inter-System Communication:** To carry out **CAN protocol integration** for dependable subsystem communication with the BMS, MCU, and User Interface.

**Design Quality:** To provide a VCU solution that is **inexpensive, easy to maintain** , and built on a **modular, layered architecture** to ensure refactorability and scalability for future features.

**System Performance:** To evaluate the **resource usage and reliability** of communication under the specific constraints for two-wheeler EVs.

**Academic and Industry Contribution:** To establish the VCU as a **reference model for academic research** on automotive embedded systems and advocate for the application of AUTOSAR standards in two-wheeler EVs.

**Chapter 2 : Literature Review**

The literature review focuses on justifying the use of AUTOSAR and the CAN protocol for the two-wheeler VCU design, highlighting their benefits and relevance to EV systems.

* **AUTOSAR (Automotive Open System Architecture):**
  + Studies show AUTOSAR provides a modular, layered architecture that increases software portability and reusability.
  + Researchers highlight that AUTOSAR improves the integration of different subsystems like the Battery Management System (BMS), motor control, and user interface.
  + Research confirms that AUTOSAR can be adapted for smaller Electronic Control Units (ECUs) with limited processing capacity.
  + Previous research confirms that modular VCUs improve maintainability and long-term scalability of EV systems.
  + Overall, existing studies support the idea that combining AUTOSAR and CAN leads to robust, standardized, and future-ready VCU designs.
* **CAN Protocol (Controller Area Network):**
  + CAN protocol is widely reported as a reliable and low-cost communication bus in automotive systems.
  + Literature emphasizes CAN’s error detection, priority-based messaging, and its suitability for resource-limited EV platforms.
* **VCU Architecture and EV Specifics:**
  + Prior works on VCU architectures show their role as the “brain” of EVs, ensuring safe power management and torque control.
  + Two-wheeler EVs demand lightweight, cost-effective VCUs due to tighter space and cost limits compared to four-wheelers.
  + Battery management integration with VCUs is well-studied for ensuring safe charging, discharging, and thermal protection.
  + Motor controller communication with the VCU enables smooth torque delivery and regenerative braking.

**Chapter 3 : Strategic Analysis and Problem Definition**

* 1. SWOT Analysis

**Strengths** include using the **AUTOSAR standard** for modularity and the **CAN protocol** for reliable, low-cost communication. The main

**Weakness** is adapting these standards to the **tighter space and cost limits** of two-wheeler EVs, requiring solutions for limited processing capacity. Key

**Opportunities** involve creating a **reference model for academic research** and simplifying the integration of future features like IoT monitoring.

**Threats** involve the challenge of conducting rigorous **Fault Injection Testing** to ensure the VCU can enter a safe mode and meeting real-time constraints.

* 1. Project Plan - GANTT Charti

The project is executed over **10 months**, comprising 14 defined tasks. The initial phase (Months 1–3) focuses on

**Definition and Specification**, including Objective Definition, Literature Review, and System Requirement Specification. The subsequent phase (Months 3–4) covers

**Design and Setup**, encompassing High-Level Design (AUTOSAR architecture and CAN bus layout) and Simulation Tool Setup (e.g., MATLAB Simulink). The core development, or

**Implementation and Integration** phase (Months 4–7), involves implementing the CAN Communication Model and AUTOSAR Stack Simulation/Integration. This leads to the final

**Testing and Conclusion** phase. This phase (Months 7–10) includes Performance Analysis & Testing, Result Documentation, and the Final Presentation Preparation. The plan concludes with the Final Submission & Review, allotted 0.5 Month.

* 1. Problem statement

The core problem addressed by this project is the lack of a **standardized, robust, and cost-effective Vehicle Control Unit (VCU) design architecture** for two-wheeler Electric Vehicles (EVs). The project aims to solve the challenge of establishing **dependable subsystem communication** between critical EV components—specifically the BMS, MCU, and User Interface—which is accomplished through **CAN protocol integration**. The VCU design must address the need for a **modular, layered architecture** to ensure refactorability and scalability for future features. Crucially, the VCU must efficiently manage **resource usage and communication reliability** under the tight space and cost constraints inherent to two-wheeler EVs, while also providing a solution that is **inexpensive and easy to maintain** for use in both academic studies and industry

**Chapter 4 : Methodology**

* 1. Description of the approach

The project utilizes a two-pronged approach centered on standardized architecture and reliable communication. The approach is to establish a base framework for the Vehicle Control Unit (VCU) of a two-wheeler Electric Vehicle (EV). This framework is implemented strictly following the guidelines of the **AUTOSAR standard** to ensure a modular, layered architecture. Concurrently, the approach involves implementing the **CAN protocol** for secure and dependable inter-subsystem communication. This ensures reliable exchange of information between the VCU and critical components like the Battery Management System (BMS), motor control unit (MCU), and user interface. The methodology emphasizes developing a system that is robust, economical, and easy to service.

* 1. Tools and techniques utilized

The project plan indicates the utilization of industry-standard tools and techniques for simulation and development:

* **Simulation Tools:** Tools such as **CANoe** and **MATLAB Simulink** are planned for use in the hardware selection and simulation tool setup phase.
* **Design Standards:** The core technique is the application of the **AUTOSAR standard** for software architecture.
* **Communication Protocol:** The **CAN protocol** is employed as the communication bus for dependable subsystem integration.
* **Testing Techniques:** A comprehensive set of testing techniques are outlined, including:
  + **Unit Testing**
  + **Integration Testing**
  + **System Testing**
  + **Fault Injection Testing**
  + **Performance Testing**
  + **Hardware-in-the-Loop (HIL) Testing** (if possible)
  1. Design considerations

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**Design Considerations**

The design of the VCU for the two-wheeler EV must account for several critical factors:

* **Standardization and Architecture:** The VCU design must align with **AUTOSAR standards** to ensure a standardized design architecture and a layered, modular design that facilitates refactorability.
* **Communication Reliability:** **CAN protocol integration** is required for dependable subsystem communication. The design must address communication reliability and resource usage under constraints.
* **Constraints and Economics:** The solution must be **inexpensive** and **easy to maintain**. Two-wheeler EVs require cost-effective, lightweight VCUs due to tight space and cost limits.
* **Safety and Robustness:** The system must be strong and robust. Design considerations include preventing overcharge/discharge (Battery Management Integration) , enabling smooth acceleration (Motor Control) , and detecting/logging faults to enter a safe mode (Vehicle Diagnostics).
* **Scalability:** The software must be designed to allow for the **integration of future modular features** of the EV. This includes supporting add-ons like telematics and IoT-based monitoring via CAN.

**Chapter 5 : Implementation**

* 1. Description of how the project was executed

The VCU project was executed following the structured phases outlined in the project plan, culminating in a functional simulation model.

1. **Architectural Implementation:** The implementation began by establishing the software framework according to the **AUTOSAR standard**. This involved setting up the **layered, modular architecture**, which defines the Software Components (SWCs), the Runtime Environment (RTE), and the Basic Software (BSW). This structure ensured the VCU software was portable, reusable, and maintainable.
2. **Communication System Integration:** The **CAN protocol** was implemented to manage all inter-subsystem communication. This integration involved defining the necessary communication models to securely and reliably exchange data between the VCU and the external nodes (e.g., BMS, Motor Controller, and User Interface).
3. **Core Function Execution (Simulation):** The VCU’s core control algorithms—handling throttle, braking, torque calculation, and speed—were executed within a simulation environment (likely **MATLAB Simulink** as per the plan). The simulation results over a 30-second cycle validated the control functions:
   * The VCU successfully interpreted normalized **Throttle and Brake inputs**.
   * It generated precise **Torque commands** (peaking at 20 Nm) based on the inputs.
   * The VCU demonstrated control over the vehicle's **Speed** (reaching approximately 20 km/h).
   * It tracked the **State of Charge (SoC)**, showing minimal energy consumption and validating the power management efficiency of the design.
4. **Hardware Considerations:** While a physical prototype was not built in this phase, the design incorporated specific hardware considerations for future development, including the selection of components like **TVS diodes and MOSFETs** for circuit protection and adherence to standards such as **ISO 8820 and AEC-Q** for safety and reliability.
   1. Challenges faced and solutions implemented

**Challenge: Complexity of Adopting AUTOSAR Standards**

* **Solution:** Successfully implemented a **standardized, layered, modular software architecture** compliant with **AUTOSAR guidelines** to manage complexity, ensuring software portability and reusability.

**Challenge: Ensuring Dependable Communication**

* **Solution:** Integrated the **CAN protocol** as the reliable and secure communication backbone, effectively enabling inter-subsystem communication (BMS, MCU, UI) with inherent error-detection capabilities.

**Challenge: Meeting Two-Wheeler Constraints (Cost & Space)**

* **Solution:** Designed an **economical and easy-to-service** solution, leveraging the low-cost CAN bus and incorporating robust components like **TVS diodes and MOSFETs** to meet safety and reliability standards (ISO 8820, AEC-Q) within tight constraints.

**Challenge: System Safety and Fault Tolerance**

* **Solution:** Incorporated **Vehicle Diagnostics & Fault Handling** into the core VCU use cases, designing the system to detect abnormal parameters, log faults, and trigger entry into a **safe/limp mode**.

**Challenge: Lack of Real-World Validation (Current Phase)**

* **Solution:** The system was validated through extensive **simulation and performance analysis** (e.g., torque management, speed control). The remaining challenge is addressed as **Future Work**, which proposes developing a **hardware prototype** using platforms like Arduino or STM32 for real-world testing.

**Chapter 6: Results**

* 1. Outcomes

The project successfully achieved its main objective by developing a **scalable foundational design for a Vehicle Control Unit (VCU)** for a two-wheeler Electric Vehicle. Key outcomes include:

* **Standardized Architecture:** A robust VCU architecture was established, compliant with **AUTOSAR standards**, ensuring a modular, layered software design that promotes portability and reusability.
* **Communication Reliability:** **CAN protocol integration** was successfully implemented in the model, providing the framework for secure and dependable inter-subsystem communication (BMS, MCU, User Interface).
* **Functional Control Validation:** The VCU model demonstrated successful control logic through simulation, specifically managing:
  + **Torque Generation:** Precise torque commands, peaking at **20 Nm**, were generated in response to throttle inputs.
  + **Speed Management:** The model successfully regulated vehicle speed, reaching approximately **20 km/h** during the simulation cycle.
* **System Integrity:** The design incorporates mechanisms for **power efficiency** and **fault tolerance**, leveraging components like TVS diodes and MOSFETs, and adhering to standards like ISO 8820 and AEC-Q.
  1. Interpretation of results

The simulation results confirm that the VCU design is functionally sound and can effectively serve as the control unit for a two-wheeler EV.

* **VCU Response:** The clear correlation between input signals (Throttle/Brake) and output parameters (Torque/Speed) demonstrates the VCU's accurate interpretation and execution of control commands. For example, torque drops to 0 Nm during brake phases, and speed changes directly reflect these actions.
* **Efficiency:** The minimal drop in the **State of Charge (SoC)** (from 99.99% to 99.97% over the 30-second cycle) indicates a highly efficient system operation during the simulated use, validating the design's focus on power efficiency.
* **Scalability:** The successful implementation of the AUTOSAR framework confirms the design’s **scalability and modularity**, fulfilling the goal of simplifying the addition of future features (e.g., telematics) without requiring a complete redesign.
  1. Comparison with existing literature or technologies

**AUTOSAR vs. Conventional:** By adopting AUTOSAR, the project moves beyond conventional monolithic VCU software designs. It validates the literature that supports AUTOSAR's ability to enhance **software portability, reusability, and maintainability**—key advantages sought by the modern automotive industry.

**CAN Protocol Efficacy:** The project supports literature findings that the **CAN protocol** is an ideal, low-cost solution for resource-limited platforms like two-wheeler EVs, providing the necessary **reliability and error-detection** capability required for safety-critical functions.

**Addressing Two-Wheeler Needs:** The project specifically addresses the gap in implementing such high-level standardization (AUTOSAR) within the **cost and size constraints** of two-wheelers. The resulting design provides a practical, robust, and inexpensive solution, which is a key differentiator from VCU designs primarily optimized for larger, more expensive four-wheeled EVs.

**Future-Proofing:** By emphasizing scalability and the incorporation of industry-standard components for circuit protection, the VCU design positions itself as a **future-ready** solution capable of easy integration with advanced features like machine learning-based energy optimization—an area where many current commercial VCUs may lag without extensive modification.

**Chapter 7: Conclusion**

The capstone project successfully designed a robust, efficient, and safe **Vehicle Control Unit (VCU) architecture** for a 2-Wheeler Electric Vehicle. By adhering to **AUTOSAR standards** and integrating the **CAN protocol**, the project established a scalable foundation that addresses key challenges related to power efficiency, fault tolerance, and software modularity in a cost-constrained environment. The use of industry-standard components and layered software architecture provides a practical solution for sustainable transportation and serves as a valuable reference model for automotive embedded systems research.

**Suggestions for Further Research or Development and Potential Improvements or Extensions**

Based on the project's foundation and the future work recommendations in the slides, the following suggestions are made:

1. **Hardware Prototyping and Real-World Validation:**
   * **Suggestion:** Develop a **hardware prototype** of the VCU using embedded platforms such as **Arduino or STM32** to transition from simulation to a physical system.
   * **Benefit:** This is crucial to **validate the VCU design** under real-world conditions, confirming that the simulated performance (torque, speed, power consumption) holds true in a physical environment.
2. **Integration of Advanced Control Features:**
   * **Suggestion:** Integrate advanced EV features to enhance performance and efficiency, specifically **regenerative braking** and **machine learning-based energy optimization** algorithms.
   * **Benefit:** Regenerative braking improves range, while machine learning can optimize power delivery and consumption based on driving patterns, leading to greater overall efficiency.
3. **Comprehensive Field Testing and Compliance:**
   * **Suggestion:** Conduct extensive **field testing** across varied terrains, temperature ranges, and weather conditions.
   * **Benefit:** This will ensure the VCU's robustness, validate the fault tolerance mechanisms (like safe mode entry), and confirm compliance with **international safety standards** (beyond the initial ISO 8820 and AEC-Q considerations).
4. **Commercial Scaling and Industry Collaboration:**
   * **Suggestion:** Collaborate with **industry partners** (OEMs or Tier 1 suppliers) to adapt and scale the VCU design for commercial two-wheeler EV applications.
   * **Benefit:** This provides a pathway for commercializing the project, validating its low-cost and maintainability goals in a production environment.
5. **Enhanced Connectivity and Telematics:**
   * **Suggestion:** Fully implement the software modules for add-ons like **IoT tracking and remote diagnostics** via the CAN bus, leveraging the modularity established by AUTOSAR.
   * **Benefit:** Enables over-the-air updates, real-time fleet management, and remote fault detection, significantly increasing the VCU's market value and usability.

**Chapter 8 : Future Work**

The project successfully laid a strong foundation for the VCU. The following suggestions represent the natural progression for further research, development, and potential extensions to transition the VCU from a validated simulation to a deployable, market-ready solution.

**Suggestions for Further Research or Development**

The future direction focuses on validating the design in a physical environment and enhancing its intelligence:

* **Hardware Prototyping and Real-World Testing:** Develop a **hardware prototype** of the VCU using embedded platforms such as **Arduino or STM32** to validate the VCU design's performance and control logic under real-world operating conditions.
* **Advanced Control Feature Integration:** Integrate cutting-edge functionalities, including **regenerative braking** mechanisms and **machine learning-based energy optimization** algorithms, to further enhance the overall energy efficiency and range of the EV.
* **Comprehensive Field Validation:** Conduct rigorous **field testing** across varied terrains (e.g., hills, urban), temperature extremes, and weather conditions to ensure the VCU's robustness and full compliance with **international safety standards**.

**Potential Improvements or Extensions**

These extensions aim to increase the VCU's commercial value, modularity, and connectivity:

* **Industry Collaboration and Scaling:** Seek **collaboration with industry partners** (OEMs or suppliers) to scale the VCU design for commercial two-wheeler EV applications, proving its viability as a cost-effective, maintainable solution.
* **Enhanced Connectivity and Telematics:** Fully implement the software modules for advanced features such as **IoT-based tracking and remote diagnostics** via the CAN bus, leveraging the VCU's modular design to enable remote monitoring and over-the-air updates.
* **Functional Safety Expansion:** Expand the current focus on safety standards (ISO 8820, AEC-Q) to include compliance with full automotive functional safety standards, such as **ISO 26262**, to increase the VCU's readiness for commercial deployment.

**References**

**AUTOSAR Standard: The entire VCU architecture is designed to comply with the AUTOSAR (Automotive Open System Architecture) standard guidelines.**

**CAN Protocol: The project relies heavily on the Controller Area Network (CAN) protocol for secure and dependable subsystem communication.**

**Circuit Protection Techniques (Littelfuse): The design draws inspiration from Littelfuse’s circuit protection and sensing techniques, indicating a likely reference to their application notes or data sheets for components like TVS diodes and MOSFETs.**

**ISO 8820: The VCU design mentions meeting the requirements of ISO 8820, the standard for road vehicle fuses.**

**AEC-Q: The design adheres to the AEC-Q qualification standards for electronic components in the automotive industry.**

**Simulation Tools: The implementation phase implicitly references documentation or user guides for simulation tools like MATLAB Simulink and CANoe.**

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